Simplified travel demand modelling for developing cities: The case of Addis Ababa

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1. Introduction

Low-income cities in developing countries lack sustainable transport network planning tools. Their networks are often planned and implemented with pure speculation. No rational explanation can be given to policy decisions affecting the transport system, nor is there a rational basis for urban transport network plans. To transform this common practice into a more systematic approach, there is a need for strategic planning. It is the most neglected planning dimension in low-income cities. Strategic plans deal with the overall structure and capacity of the main transport network, and also deal with the relationship between transport and land-use.

Travel demand modelling can be used as a strategic planning tool. However, application of the conventional modelling system, as practiced in developed countries, produced unsatisfactory results. Thomson (1983) has explained in detail the apparent weaknesses of the conventional method for developing countries. The focus should, then, be on applying simplified modelling techniques to developing cities.

The main objective of this study was to asses the applicability of one specific simplified travel demand model as a tool for strategic transport network planning. In addition, an answer was sought to the question: 'can a simplified model be developed not requiring the use of licensed software, that can be utilised by competent municipal engineers in developing cities as a forecasting tool to assist transport network planning?' A special concern was that the model must, in a transparent way, include all modes of travel (walking, where relevant two-wheelers, public transport modes and private motor vehicles), and allow to investigate the implications of different modal split scenario's that include pedestrian and bicycle traffic. The reason for this concern is that these modes, and pedestrian traffic in particular, serve the majority of travellers in many low-income cities, and that therefore the use of the standard travel demand model with a focus on private car travel or the car/public transport modal choice is less suitable.

The four steps – trip generation, distribution, modal split and traffic assignment - were modelled within a spreadsheet environment. The study addressed only passenger transport. Urban freight transport was not included in the modelling. The observed traffic flows, derived from traffic counts specifying the share of freight vehicles, were corrected for freight traffic.

2. Literature review

According to Fischer (1987), the main objective of travel demand analysis is to provide an understanding of why people travel, to identify the essential factors influencing their travel decisions and to provide information for the evaluation of alternative transportation policies by predicting the travel consequences of alternative policies or planning. In practical terms, the ultimate purpose of urban travel demand modelling is to provide a tool with which one may predict, or forecast, urban travel patterns under various conditions. These conditions may represent the state of the transportation network or, generally, that of the urban area at a future time. The conditions could also be policy alternatives under which different travel patterns can be analysed.

Travel demand models have been in use since the late 1960's and a lot of criticism is thrown at them. This is mostly aimed at the standard four stage aggregate model. Different authors express their views relating to the weaknesses of the conventional method. It is worthwhile to mention that the criticism sometimes doesn't concentrate only on the model as such, but on the planning and decision making aspects as well. Bruton (1988) expressed that the conventional four step model is criticised on the grounds that it is concerned more with simulating or reproducing known situations, than predicting the way travellers behave now or will behave in the future. The main weakness of the conventional model is generally understood to be its failure to allow for consequences of change. Trip rates are assumed to be independent of the transport changes being considered. Land uses are assumed to remain equal in the analysis of alternative transportation improvements. Forecasting future travel demand by using base-year correlations makes the process non-causal, in the sense that it is not based on any logical or behavioural responses of travellers to new conditions.

Looking at many of these criticisms, one wonders why developing cities should go through such travel demand analysis procedures. Even, there are some who argue that developing countries should only work on better traffic management and concentrate more on low-cost, short-term improvements (Thomson 1983).

Even if it is true that low cost measures and traffic management works are essential to address some of the existing problems, Ortúzar and Willumsen (1998) point out that weak transport planning, emphasis on the short term and mistrust in strategic transport planning in the past had brought its own lessons. It was learnt that 'problems do not fade away under the pressure of mild attempts to reduce them through better traffic management; old problems reappear with even greater vigour, pervading wider areas, and in their new forms they seem more complex and difficult to handle.'

Furthermore, no adequate replacement has been proposed to the transport planning model and practitioners still extensively use it in part or in its entirety. The logic of the modelling process, and the representation of the ways in which decisions are made has remained to be its strength (Banister 1994). From the perspective of the state of the practice, the choice of this approach is not because it is the best available but because it is often the only approach available, given current institutional requirements and financial limitations (McNally 2000). Therefore, as the proponents of modelling theory argue, some guide as to what the future might hold in terms of travel patterns is better than pure speculation. Yet, the conventional travel demand models appear to be less suitable for the developing world, and hence the emphasis should be on simplified models geared to the urban travel conditions and planning needs of developing countries (Bayliss 1992).

An important question that needs to be addressed at this juncture is: 'what is simplified modelling'. Is there an accepted definition and procedure as to what the term 'simplified modelling' encompasses? After all, there are a whole range of modelling approaches in between the extremes of using no formal models at all and employing the most advanced and complex simulation techniques. Literature reviewed doesn't seem to offer a specific global definition. Nevertheless, different authors have put forth the idea and reported about the application of simplified modelling to different cases.

The repeating theme that comes when dealing with simplified modelling is *data requirement*. Collecting and processing enormous amounts of data has been seen as a main setback to utilising conventional transport modelling methods in developing country cities. Hence a simplified modelling approach is desirable that requires minimum data input, which can be obtained in a reliable manner, and that utilises available data. Another important aspect of simplification is the need for a simple model structure. A procedure that is transparent and has a simple analytical processes, i.e. without 'black-box effects', is confirmed to be the basis for simplified modelling.

3. Zonal and network definition

3.1 Addis Ababa profile

Addis Ababa is the capital city of Ethiopia. The city administration territory extends over 540 km^2. The 2004 population of the city is estimated to be 3 million. A household survey, conducted as part of an Urban Transport Study during 2004 has revealed many socio-economic characteristics of the people of Addis Ababa. The average household size is 5.08. The people are young in age with the median value being 18-40 years. Income is low, nearly 50% of the people are below poverty line and about 23% are in absolute poverty (ERA 2005).

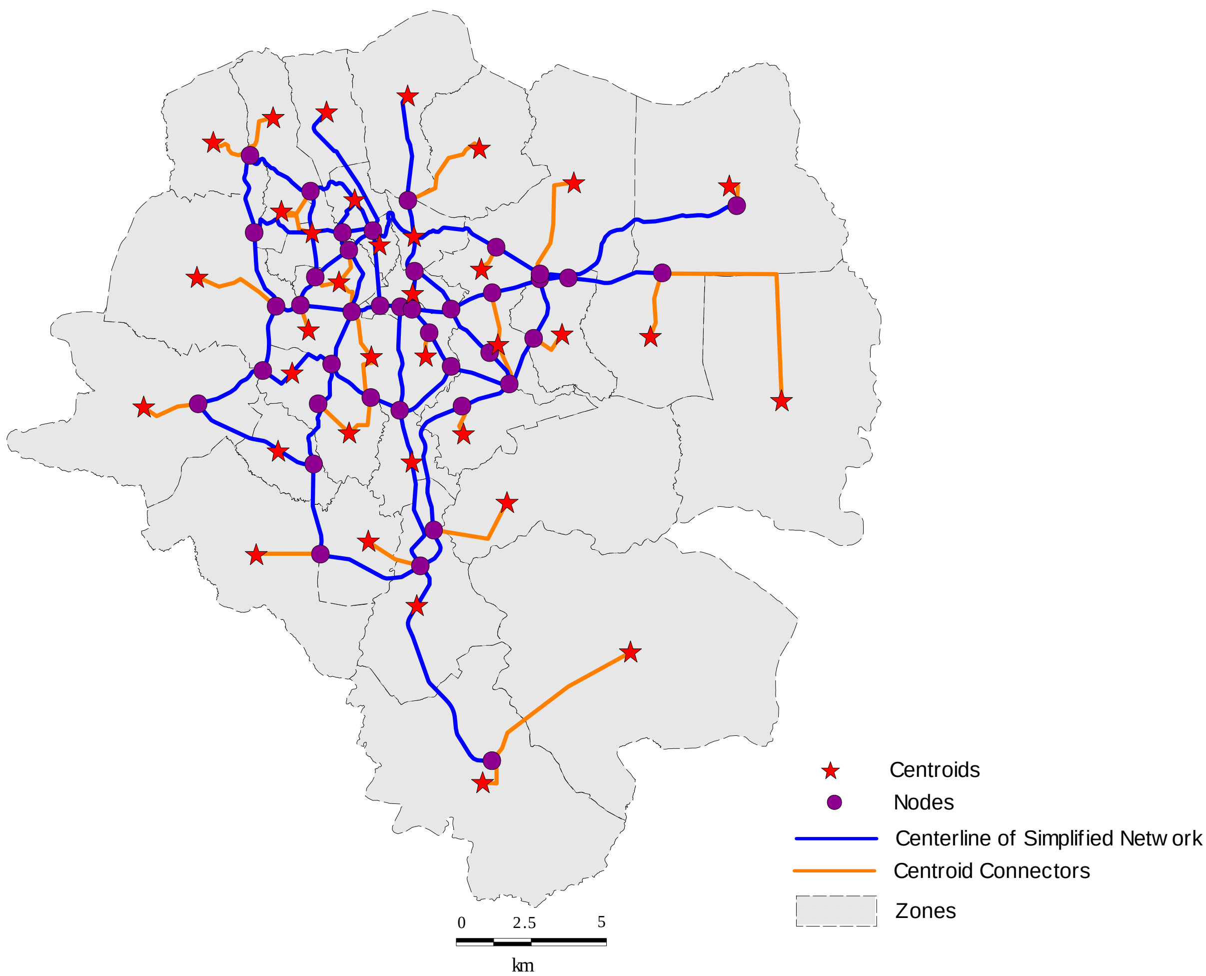
ERA's (2005) Findings Report provided the salient characteristics of the trip making behaviour of the people of Addis Ababa. A total of 3.4 million trips per day are generated, on average, in the city. The overall Per Capita Trip Rate (PCTR), including persons of all age groups is 1.08. Excluding the population in the age group 0-5, the PCTR is reported to be 1.14. Walking is the predominant mode, accounting for a share of 60.5% of all trips. The Minibus comes next with a share of 20.6%, followed by City Bus with a 10.9% share. The average trip length including walking is 3.3km. According to the study, the total travel demand generated in Addis Ababa, on an average day, is 11.05 million-passenger-km. The Minibus takes the highest share of travel demand with 34%, while the walking share drops to 27.3%.

It is important to note that the modal share of car trips is very low, with 4.7%. Vehicle ownership in Addis Ababa is very low. Nearly 90% of households do not own a vehicle. Another important finding of the study is the very low interaction between city households and the external region. Of the total trips produced, almost 99.75% are intra city, i.e. they have their points of origin and destination within the study area. However, it is also reported that the outer cordon survey revealed a reasonable movement of people and goods into/out of the city from external regions.

3.2 Demarcating traffic analysis zones and simplified network

Addis was divided into 35 traffic zones under this study. The zoning was carried out to ensure that each demarcated zone falls within the formal administrative zone of sub cities. Hence the traffic zones are made of clusters of *kebele* administrations, which is the smallest administrative unit of the city. Moreover effort was made to ensure that zones are as homogeneous as possible. The aim of this simplified modelling exercise was to use as low divisions as possible and test the results of the model. Generally, the lower the number of zone divisions, the less data collection requirement.

Figure 3.1: Zones and network presentation



Addis has 472km of paved road network. Out of the total paved roads, 25% are arterial 14% are sub arterial 27% are collector and 35% are local roads. For this simplified modelling work, arterial roads are chosen. The choice is done in order that all zones are possibly connected with the road network. The total length of selected roads is 137km (of 2x1, 2x2 or 2x3 lanes).

A total of 65 links, 40 nodes, 35 connectors, and 35 centroids were identified for the model. Figure 3.1 shows the final map that was used as a base for modelling.

4. Data

The purpose of this simplified travel demand modelling is to provide a model for estimation of traffic numbers on main road corridors for scenario analysis of the urban transport system that can be applied with a limited set of input data, for which the collection and analysis is manageable. The required key input data grouped into source and type are presented below:

a) *Administrative (Census or other)*

Data under this group are sourced from offices where records of data are kept for administrative purposes. Relevant offices keep track of statistical data as part of their main work activities. The municipality and local administrations keep track of population figures. Education bureaus keep records of students. Labour and statistics offices keep records of employment data. These data are basically reflections of land use and the economic activities of the area. Hence, zonal data that were made available for this study are: population, employment, and student enrolment.

b) *Household survey (inventory)*

Data under this group need to be collected by means of a household (HH) travel survey. This study used the HH survey data obtained from the ERA's (2005) Findings Report. The ERA transport study carried out 5,500 household interviews during 2004.

For this simplified modelling, the HH survey data are classified into two: zonal data, and city trip characteristic data. The specific zonal data and the city trip characteristics data used in the model are presented below:

Zonal data:

Resident workers; Resident students; Work trip productions and attractions; education trip productions and attractions; other purpose trip productions and attractions.

City trip characteristic data:

Table 4.1: Modal share of trips

Mode	**Share of trips**
Walk	60.5 %
Car	4.7 %
City Bus	10.9 %
Mini Bus Taxi	20.6 %
Others	3.3 %

Table 4.2: Average trip length for each mode of travel

Mode	**Average Distance (km)**
Walk	1.4
Car	7.4
City Bus	7.5
Mini Bus Taxi	5.4
Others	8.1

Table 4.3: Share of trips by distance group

Distance	**Share of trips**
0-2 km	53%
2-4 km	21%
4-8 km	15%
8-12 km	7%
>12 km	4%

Table 4.4: Income versus modal share of main modes of travel

HH income Birr/Month	**Up to 300**	**300 - 500**	**500 - 800**	**800 - 1000**	**1000 - 2000**	**2000 - 4000**	**>4000**
Walk	12.4%	16.6%	14.0%	6.6%	9.4%	1.4%	0.2%
Car	0.1%	0.3%	0.5%	1.1%	1.8%	0.8%	0.3%
Minibus	1.5%	2.9%	3.0%	1.2%	1.9%	0.3%	0.1%
Bus	1.3%	3.3%	4.6%	3.2%	6.0%	1.9%	0.4%
Others	0.1%	0.2%	0.9%	0.6%	1.0%	0.4%	0.0%

A distinction should be clarified between the variables "Resident workers" and "Employment". The workers variable is the total number of employed persons residing in a zone, while the employment variable represents the number of employees whose place of work is within a zone. It should be noted that while these variables are mentioned here under the HH survey data, because the estimates of labour participation and of work place location distribution were based on the HH survey, the scaling of these variables was based on census data.

c) Network and Traffic data

Road network inventory: In this study, inputs for the model were: topology of the network (map), and road section length, number of lanes and observed average traffic flow speed. The availability of a digital map of the network expedited the network definition exercise. Network data and a digital map of the road network for this study were made available by the Addis Ababa City Roads Authority.

Traffic counts: Independent data regarding the actual traffic volume on selected links on the network is necessary to validate the model output. These should be of the same year as the household survey. As the model is limited to passenger traffic, ADT without freight traffic is taken for comparison.

It should be noted that while traffic count data are used to compare the model's traffic volume estimates with observed traffic flows, the key calibration of the model is carried out at the distribution and modal split stage (average O/D trip distances equal to observed average trip distances, and modal split equal to observed one – observed in both cases: by means of household survey).

Table 4.6 summarises the data requirements.

Table 4.6: Summary of data requirement

Data	Generation	Distribution	Modal Split	Assignment	Remark
City travel characteristics data - household survey					
Modal share of trips			X		For development of base matrices
Average trip lengths for each mode		X	X		
Share of trip distances		X	X		
Income versus mode of travel			X		
Zonal data - Household survey					
Trip production	X				
% work, education and other trips	X				
Resident workers	X				
Resident students	X				
Trip attraction	X				
Share of trips by income		X			
Zonal data - Census					
Population	X				
Employment	X				
Student enrolment	X				
Network data					
Road length (per section)				X	
Number of lanes ..				X	
Traffic flow speed ..				X	

5. Development of mobility matrices

This simplified model uses aggregate modal choice data. To obtain the best accuracy in predictions for future years, modal-split market segmentation is carried out. This means that the aggregate modal split is considered for market segments that can be expected to be, in themselves, more constant over time than the market as a whole, shifts in modal choice being, to a considerable extent, caused by the transition of travellers from one market segment to another. For example in the Addis case: getting to a higher income level allowing the use of public transport for more trips, or, in the highest income class, obtaining a private motor vehicle.

The segmentation variables used are: trip distance, trip purpose and income of the traveller. An alternative for this last one would be vehicle ownership of the traveller, but insufficient data were available in this case study to use it.

Since market-segmented modal choice matrices provide a detailed insight into the actual mobility of the urban population, they are referred to as *Mobility Matrices.* They show over what distances and in what modal shares per distance class people travel, and how the pattern differs by trip purpose and income group.

The basic matrices used in the simplified model as specified in this paper for trip distribution and modal split modelling stages are listed below. The complete - desirable market segmentation mentioned above could not be applied in the current test, because the basic records of the 2004 Addis household travel survey were not available for this study, only the report presenting the aggregate survey findings. This findings report didn't include the cross-tabulations providing immediate estimates of the different mobility matrices by market segment. This made it necessary to derive best estimates indirectly (as explained below), and to omit the segmentation by trip purpose. For validation of the model's traffic volume calculations on the arterial road network against observed ADT flows, leaving out the differences in modal choice per trip purpose isn't problematic (the average over all purposes *is* the current overall pattern). However, for forecasting it is desirable to include representing shifts in size between trip purpose segments, the modal split pattern differing significantly between trip purposes.

The basic matrices used in this study are:

- Overall Mobility matrix (mode versus distance; total urban travel market)
- Income versus distance matrix
- Mobility matrices for different income groups

5.1 Develop mobility matrix

The data available to develop the mobility matrix for Addis Ababa are:

- Modal share of trips (Table 4.1)
- Average trip lengths for each mode of travel(Table 4.2)
- Share of trip distances (Table 4.3)

The problem to derive the matrix has the following form:

Trip Distance ***Mode***	**0-2 km (1 km)**	**2-4 km (3 km)**	**4-8 km (6 km)**	**8-12 km (10 km)**	**>12 km (18 km)**	**Total**	**Average Distance (km)**
Walk	?	?	?	?	?	*60.5 %*	*1.4*
Car	?	?	?	?	?	*4.7 %*	*7.4*
City Bus	?	?	?	?	?	*10.9 %*	*7.5*
Mini Bus Taxi	?	?	?	?	?	*20.6 %*	*5.4*
Others	?	?	?	?	?	*3.3 %*	*8.1*
Total	*53%*	*21%*	*15%*	*7%*	*4%*		

As can be referred from the formulated problem, there are 25 unknowns and 15 independent constraints. The problem is solved through the tri-proportional fit method. The procedure starts with initial estimates of matrix-cell values, by applying the direct percentage on the daily number of trips. Then the matrix is further improved to reflect the absolute deviation of distance group from the average distance of each mode. This is done by multiplying the values in the matrix by a factor: $\frac{1}{(/d_i - d_{avg}/)^f}$

where d_i is the average distance of class, d_{avg} is the average distance of modes, and f is a factor which is initially set to 2.

Then, iteration similar to Furness is applied, which involves successive corrections by rows and columns to satisfy row and column summation constraints. The iteration stops when corrections are 100% satisfied. Finally a value for the factor *f* is searched such that the average distance of modes coincides with the target average distances. The final result is given in Table 5.1 below.

Table 5.1: Mobility Matrix for Addis Ababa

Trip Distance ***Mode***	**0-2 km (1 km)**	**2-4 km (3 km)**	**4-8 km (6 km)**	**8-12 km (10 km)**	**>12 km (18 km)**	**Total**	**Average Distance (km)**
Walk	50.2%	9.7%	0.3%	0.3%	0.0%	*60.5%*	1.4
Car	0.4%	1.2%	1.2%	1.2%	0.6%	*4.7%*	7.4
City Bus	0.9%	2.8%	2.7%	3.0%	1.5%	*10.9%*	7.5
Mini Bus Taxi	1.5%	6.8%	10.2%	1.0%	1.0%	*20.6%*	5.4
Others	0.2%	0.7%	0.4%	1.5%	0.5%	*3.3%*	8.6
Total	*53%*	*21%*	*15%*	*7%*	*4%*		

5.2 Develop income versus distance matrix

The data available to develop income versus distance matrix are:

- Average trip lengths for each mode (Table 4.2)
- Share of trip distances (Table 4.3)
- Income versus mode of travel (Table 4.4)

First, average distance of each income group is calculated, and then the problem is formulated similar to the one shown above as follows:

Distance ***Income (Birr/Mon)***	**0-2 km (1km)**	**2-4 km (3 km)**	**4-8 km (6 km)**	**8-12 km (10 km)**	**>12 km (18 km)**	**Total**	**Average Distance (km)**
Up to 300	?	?	?	?	?	*16%*	2.5
300 - 500	?	?	?	?	?	*24%*	2.9
500 - 800	?	?	?	?	?	*23%*	3.4
800 - 1000	?	?	?	?	?	*12%*	3.8
1000 - 2000	?	?	?	?	?	*19%*	4.1
2000 - 4000	?	?	?	?	?	*4%*	5.2
>4000	?	?	?	?	?	*1%*	5.6
Total	*52.85%*	*21.25%*	*14.90%*	*7.00%*	*4.00%*		

Using a similar iteration procedure mentioned under the foregoing section the solution is given in Table 5.2 below:

Table 5.2: Income Vs Distance Matrix

Distance / *Income*	0-2 km (1km)	2-4 km (3 km)	4-8 km (6 km)	8-12 km (10 km)	>12 km (18 km)	Total	Average Distance (km)
Up to 300	12.0%	1.8%	1.1%	0.8%	0.5%	*16%*	2.5
300 - 500	10.1%	11.3%	1.4%	0.9%	0.6%	*24%*	2.9
500 - 800	12.8%	5.1%	2.9%	1.7%	1.0%	*23%*	3.4
800 - 1000	6.7%	1.3%	2.3%	1.2%	0.7%	*12%*	3.9
1000 - 2000	9.9%	1.6%	4.5%	2.0%	1.1%	*19%*	4.3
2000 - 4000	1.2%	0.1%	2.1%	0.5%	0.2%	*4%*	5.5
>4000	0.1%	0.0%	0.6%	0.1%	0.0%	*1%*	5.8
Total	*53%*	*21%*	*15%*	*7%*	*4%*		

5.3 Develop mobility matrices for different income groups

The first step will be determining the income classification. It is recommended that the income class be divided in to three groups: low income, medium income, and high income. The income threshold is proposed to coincide with those having similar trip making characteristics. To figure out those having similar trip characteristics, the income versus mode of travel matrix is recalculated in such a way that share of mode for each income group is known. Table 5.3 below shows the converted income versus mode matrix. It should be noted that the income classification tables presented herewith are based on number of trips not number of population.

Table 5.3: Income versus mode

Birr/Month	unto 300	300 - 500	500 - 800	800 - 1000	1000 - 2000	2000 - 4000	>4000
Walk	80%	71%	61%	52%	47%	30%	22%
Car	1%	1%	2%	8%	9%	17%	29%
Minibus	10%	12%	13%	10%	10%	6%	8%
Bus	8%	14%	20%	25%	30%	40%	40%
Others	1%	2%	4%	4%	5%	7%	1%
	100%	100%	100%	100%	100%	100%	100%

From the table above it can be concluded that, based on modal choice characteristics, it makes sense to simplify to three distinct income groups, as shown in Table 5.4.

Table 5.4: Income classification of trips

Birr/Month	*Class*	*Percentage*
Up to 800	Low-income	62%
800 - 2000	Medium-income	33%
> 2000	High-income	6%

Hence Table 5.4 above can be converted into class versus distance matrix as shown in Table 5.5 below:

Table 5.5: Income class versus distance group

Trip Distance / ***Income Class***	**0-2 km**	**2-4 km**	**4-8 km**	**8-12 km**	**>12 km**	**Total**
Low	33%	18%	5%	3%	2%	*62%*
Medium	18%	3%	7%	3%	2%	*33%*
High	2%	0.2%	2%	1%	0.3%	*6%*
Total	*53%*	*21%*	*15%*	*7%*	*4%*	

Again, Table 5.5 above can be recalculated as presented in Table 5.6 below:

Table 5.6: Income class versus distance converted

Trip Distance / ***Income Class***	**0-2 km**	**2-4 km**	**4-8 km**	**8-12 km**	**>12 km**	**Total**
Low	54%	29%	9%	5%	3%	*100%*
Medium	54%	9%	22%	10%	5%	*100%*
High	36%	4%	44%	11%	5%	*100%*

Likewise, Table 4.3 can be converted as class versus mode matrix as presented in Table 5.7 below.

Table 5.7: Class versus mode

	Low	**Medium**	**High**	**Total**
Walk	43%	16%	1.6%	*60%*
Car	1%	3%	1.0%	*5%*
Minibus	7%	3%	0.4%	*11%*
Bus	9%	9%	2.2%	*21%*
Others	1%	1%	0.4%	*3%*
	62%	*33%*	*6%*	

And Table 5.7 can be recalculated and presented as Table 5.8:

Table 5.8: Class versus mode converted

	Low	**Medium**	**High**
Walk	69%	49%	29%
Car	1%	9%	19%
Minibus	12%	10%	6%
Bus	15%	28%	40%
Others	2%	4%	6%
Total	100%	100%	100%

Once the necessary matrices are derived, mobility matrices for the three income groups can be derived using a similar iteration procedure mentioned before.

Mobility matrix for low-income group

The daily number of trips by the low income group needs to be established first. Hence, the daily number of trips by low income group can be calculated by as follows:

$$T \times LIT$$

Where T is the total number of trips per day and LIT is the share of trips made by low income group, which is 62%, 3,352,732 x 0.62

Daily trip by low income group is: 2,072,762

After the total number of trips by the low income group is calculated, the problem for the matrix can be formulated by taking the low income modal share and distance share from Table 5.6 and Table 5.8 as follows:

Trip Distance	**0-2 km**	**2-4 km**	**4-8 km**	**8-12 km**	**>12 km**		**Average**
Mode	**(1km)**	**(3 km)**	**(6 km)**	**(10 km)**	**(18 km)**	**Total**	**Distance (km)**
Walk	?	?	?	?	?	*69.4%*	*1.4*
Car	?	?	?	?	?	*1.3%*	*7.4*
City Bus	?	?	?	?	?	*12.0%*	*7.5*
Mini Bus	?	?	?	?	?	*14.9%*	*5.4*
Others	?	?	?	?	?	*2.4%*	*8.1*
Total	*54%*	*29%*	*9%*	*5%*	*3%*		

The final matrix after solving the problem is shown in Table 5.9:

Table 5.9: Mobility matrix of low-income group

Trip Distance / ***Mode***	**0-2 km (1 km)**	**2-4 km (3 km)**	**4-8 km (6 km)**	**8-12 km (10 km)**	**>12 km (18 km)**	**Total**	**Average Distance (km)**
Walk	53.1%	16.1%	0.1%	0.1%	0.0%	*69.4%*	1.4
Car	0.1%	0.5%	0.3%	0.3%	0.2%	*1.3%*	7.4
City Bus	0.5%	4.6%	2.1%	3.1%	1.7%	*12.0%*	7.5
Mini Bus Taxi	0.5%	7.4%	6.1%	0.5%	0.6%	*14.9%*	5.0
Others	0.1%	0.7%	0.2%	1.1%	0.4%	*2.4%*	8.6
Total	*54%*	*29%*	*9%*	*5%*	*3%*		

The average trip distance of the low income group is calculated to be 3.0km.

Similar to the procedure employed for the low income group, mobility matrices were developed for medium income group and high income group, whose average distances were calculated to be 4.1km and 5.2km respectively.

Once mobility matrices were estimated using aggregate city trip characteristics data, the simplified travel demand modelling procedure was developed as explained in the next section.

In cases where household travel survey records per respondent are available, the estimation procedure shown above is not needed, since all mobility sub-matrices can then directly be derived from the survey.

6. The Four Modelling Steps

The first stage of the four step model is the *trip generation* model which predicts the number of trips produced and attracted per day to a traffic zone. The output of the trip generation model is total person trips productions and attractions. The second step is the *trip distribution* model which distributes all trips produced in a zone to all possible attraction zones. The output of the trip generation model is input for this model. The output of the trip distribution model is nine total person OD matrices stratified by purpose (3) and income class (3). The third step is the *modal split* model which separates the total person trip matrices into alternative modes. The outputs of trip distribution model, all person OD matrices, are the inputs for this model. The final output of the modal split model is a traffic matrix expressed in passenger car equivalent units (pce). The fourth and the last step is *traffic assignment* model that loads vehicle trips on the road network. The final output of the model was average daily traffic or peak hour traffic on each link.

6.1 Trip generation modelling

Trips are, at the generation stage, stratified by three trip purposes. These are: work trips, education, and other purposes. All three are home-based trips. None-home based trips are left out as a separate group in this study, because their share is very small (2%, compared to home-based trips). To assess the effect of this, the model was run once with inclusion of the non-home based trips, but the final output (traffic on the arterial roads) didn’t differ from the result obtained without.

Regression equations were applied to estimate trip productions and attractions per zone. The equations were tested with and without a constant term. In this study, all constant terms in the trip generation equations were insignificant (very low values for the t-statistic), so equations without a constant term were used (i.e. the average percentage of resident workers in a zone was used as an estimator of the number of work trips generated per day, etc.)

Trip productions

Total number of trips generated per day per zone in 2004 was available as input data, from the household survey. For trip purposes, only the share of each trip purpose in the ten sub-cities was available. These shares were applied to traffic zones according to the sub-city they belong, to get productions per purpose for each zone (should raw survey data have been available, these values could have been derived directly from the survey).

The explanatory variables for work, education and other purpose trip productions respectively are the number of *resident workers, resident students (incl. primary school)* and *population* in the zone. Estimates of resident workers and students were available from the household survey.

Trip attractions

The method used for estimating trip attraction is similar to that used for trip production. Regression models were used for the three purpose groups. The explanatory variables for work, education and other purpose trip attractions are, respectively, *employment number, student enrolment* and *employment* in the zone.

6.2 Trip distribution modelling

In this study, the trip distribution model has been applied separately for three trip purpose groups: work, education, and other trips. The reason for doing this is that the average trip distance differs strongly between these trip purposes (for example, work trip being on average much longer). Each trip purpose group is in turn subdivided into three income groups: low, medium, and high. Hence, the model estimates nine (3x3) origin-destination matrices.

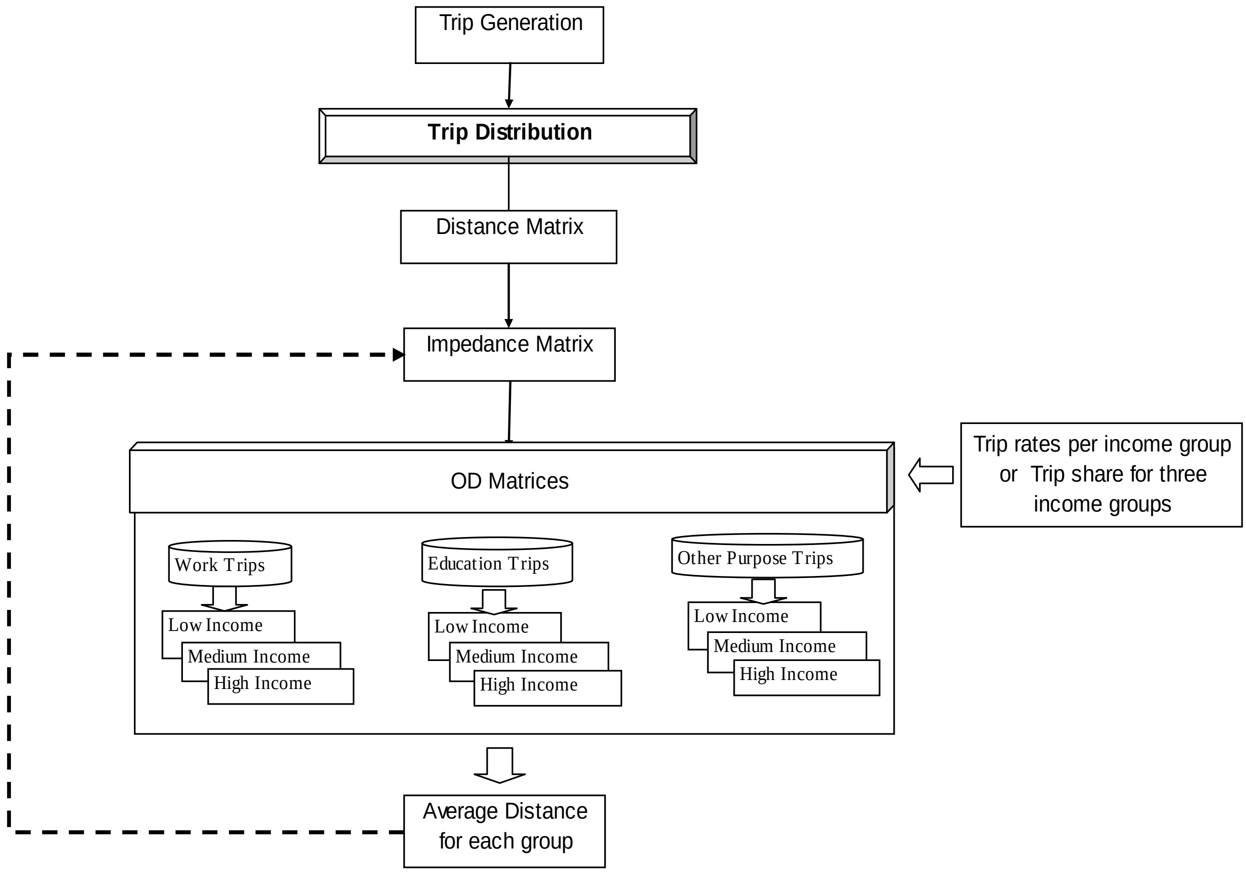
A Gravity Model -the most widely used trip distribution technique- is used. The gravity model assumes that flows between zones decrease as a function of distance separating them, just as the gravitational pull between two objects decreases as a function of the distance between them. The procedure employed for each purpose and income group is shown below.

Trip Distance Matrix

In the simplified model, it isn't immediately obvious how the distance between two traffic zones can best be quantified in order to get the best fit between the estimated O/D matrix and observed average trip distances and key O/D flows. Initially, in the model test, distances were estimated as shortest paths along the simplified (main arterial) road network, and the O/D matrix estimated with this measure of inter-zone distance. However, with this approximation of inter-zone distance no satisfactory fit can be achieved. The explanation is that the simplified network (consisting of the main arterial roads only) is a too rough approximation of the much denser actual network of roads and tracks that travellers use to provide realistic inter-zone distances. This is in particular true for short trips and trips on foot (at the distribution stage trips by all modes are included in the same manner, and hence in the Addis case, as in many low-income cities, a high percentage of the trips is on foot). It turns out that by simply using straight-line distance between zone centroids a much better and in fact satisfactory fit is obtained.

predicted for new situations, while there would also be no ground for assuming it is an invariant zone characteristic constant. This is the underlying overall logic of the simplified model: not to use unclear model-fitting parameters.

Figure 6.1: Diagram of trip distribution modelling



Trip distance of trips within one traffic zone was approximated by 0.5 the average radius of the built-up area of the zone. Higher and lower values of the intra zonal trip distance were tested (0.25, 0.75 r), but produced a less good fit between the estimated and observed intra/inter zonal trip ratio. The use of intra-zonal trip distance per separate traffic zone as a parameter that can be adapted (per zone) to achieve a perfect fit was not considered. For the base-case this could be done, but, in the absence of an underlying explanation, it could not be

Impedance matrix

The impedance of travel from zone *i* to *j* is usually defined as a function of generalized cost of travel between the two zones. One common form is $F_{ij}=C_{ij}^{-\alpha}$. For this study, the generalised cost is assumed to be the distance between zones. Hence the impedance function is calculated as $1/d_{ij}^{\alpha}$, where d_{ij} is distance between zones and α is model parameter to be determined by calibration. The calibration iterations start with $\alpha=2$, by analogy to the law of gravitation – hence the name gravity model. The impedance matrix is calculated by applying the impedance function on the distance matrix.

Trip productions and attractions

The trip productions and attractions for each zone, sub-divided by purpose of the trip, calculated in the generation model are taken as input for the distribution model. Productions and attractions by trip purpose are then further sub-divided into low, medium, and high income groups according to the trip rate per each income class (more trips per day by higher-income).

Doubly constrained iteration

Furness iteration is carried out separately for the nine income group (3) and trip purpose (3) combinations. The iteration involves consecutive correction of columns and rows till the summations are satisfactorily balanced.

At each iteration of the gravity model, the total trips attracted to each zone is adjusted so that the next iteration of the gravity model will send more or fewer trips to that attraction zone, depending on whether the immediately previous total trips attracted to that zone was lower or higher, respectively, than the trip attractions estimated by the trip generation model. After several iterations a final Origin-Destination (OD) matrix for the particular purpose and income class is produced.

Calibrate matrix

A simplified calibration procedure is employed in this study. First, the average distance of the O/D matrix is calculated to compare it with the target (observed) average trip distance of the income class concerned (calculated from the base mobility matrices). Second, the value of *a* is sought such that the average distance value of the matrix coincides with that of the actual average trip distance of the income group (/purpose). As shown during the development of base matrices, the average trip distances of low, medium and high income groups are 3.0 km, 4.1 km, and 5.2 km respectively. The average distance of a matrix is calculated with the following equation:

$$d_{avg} = \frac{\sum_{i}^{n}\sum_{j}^{n} d_{ij} T_{ij}}{\sum_{i}^{n}\sum_{j}^{n} T_{ij}}$$

where T_{ij} is number of trips between zone *i* and zone *j* and d_{ij} is the distance between the two zones and *n* is the number of zones.

6.3 Modal split modelling

The simplified modal split procedure applied in this study deviates significantly from the conventional model. The now commonly used travel demand forecasting models uses disaggregate modal split models, often on separate choice-based samples, and reflecting choice probabilities of individual trip-makers (McNally 2000), and often use combined modal split/ traffic assignment or combined modal split/distribution.

In contrast, the simplified model presented here uses mobility matrices of different travel market segments, as explained earlier. Hence the data requirement for the modal split model is in fact the data required to develop mobility matrices.

The modal split model is undertaken by taking into consideration income classes and trip distances. The modal split matrices are calculated based on mobility matrices of each income class, and the distance group of each mode. For each OD matrix table, modal split matrices are derived. The modes considered are: walk, minibus, bus, car, and other types. From the nine OD matrices, a total of 45 OD passenger travel matrices per travel mode are calculated first (measure in passenger trips). Per mode nine matrices are added up, resulting in five matrices, one for each mode, as shown in Figure 6.2. Finally, after leaving out the pedestrian traffic matrix, the four remaining mode-specific traveller OD matrices are transformed into a single "passenger car equivalent" (pce) OD traffic matrix, by applying occupancy and equivalency factors per modes of transport. Note that the choice for five modes of travel is specific for the Addis case, and should be made in each city on the basis of the actual traffic composition (for example requiring inclusion of motorised two-wheelers or of bicycles categories; the simplified model can be adapted easily by using more or less rows in the mobility matrices).

An example showing the procedure followed is presented below. Data from low income group is chosen for the purpose of explanation.

- **OD Matrix**
  The OD matrix for low-income group under work trip is taken as a case for explanation.

- **Mobility matrix**
  The mobility matrix of the low-income group will be used for this calculation, as the group under investigation is low-income. Table 6.1 below presents the mobility matrix of the low income group.

Table 6.1: Mobility matrix of low income group, example

Trip Distance / ***Mode***	***0-2 km***	***2-4 km***	***4-8 km***	***8-12 km***	***>12 km***	***Total***
Walk	*53.0%*	*13.9%*	*0.1%*	*0.1%*	*0.0%*	*67.2%*
Car	*0.1%*	*0.5%*	*0.2%*	*0.4%*	*0.2%*	*1.3%*
City Bus	*0.5%*	*2.7%*	*1.0%*	*2.3%*	*1.1%*	*7.7%*
Mini Bus Taxi	*1.5%*	*11.0%*	*7.0%*	*1.3%*	*1.2%*	*21.8%*
Others	*0.1%*	*0.5%*	*0.1%*	*1.0%*	*0.3%*	*2.0%*
Total	*55.2%*	*28.5%*	*8.5%*	*5.1%*	*2.7%*	

The above mobility matrix is converted into the following matrix where modal shares are given per trip-distance class:

Table 6.2: Converted mobility matrix, example

Trip Distance ***Mode***	**0-2 km**	**2-4 km**	**4-8 km**	**8-12 km**	**>12 km**
Walk	96.0%	48.8%	1.6%	2.7%	0.0%
Car	0.2%	1.6%	2.3%	7.5%	6.7%
City Bus	1.0%	9.3%	12.3%	46.2%	39.7%
Mini Bus Taxi	2.7%	38.4%	82.3%	24.7%	42.8%
Others	0.2%	1.8%	1.6%	18.9%	10.8%
Total	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*

- **Calculate modal split matrices**
  Trips in each cell of the OD matrix will be checked for the distance group they belong. Then the trip values in each cell will be split into modes in accordance to the share of mode by using the proportion calculated in Table 6.2. The calculation is carried out using the following conditional clauses:

  If 0 km < d_{ij} < 2 km, then *walk* = 0.96*T_{ij}, *car* = 0.002*T_{ij}, *city bus* =0.01* T_{ij}, *minibus* = 0.027* T_{ij}, *others* = 0.002* T_{ij}

  If 2 km < d_{ij} < 4 km, then *walk* = 0.49*T_{ij}, *car* = 0.016*T_{ij}, *city bus* =0.093* T_{ij}, *minibus* = 0.38* T_{ij}, *others* = 0.018* T_{ij}

  If 4 km < d_{ij} < 8 km, then *walk* = 0.016*T_{ij}, *car* = 0.023*T_{ij}, *city bus* =0.123* T_{ij}, *minibus* = 0.82* T_{ij}, *others* = 0.016* T_{ij}

  If 8 km < d_{ij} < 12 km, then *walk* = 0.027*T_{ij}, *car* = 0.075*T_{ij}, *city bus* =0.46* T_{ij}, *minibus* = 0.247* T_{ij}, *others* = 0.19* T_{ij}.

  If d_{ij} > 12 km, then *walk* = 0*T_{ij}, *car* = 0.067*T_{ij}, *city bus* =0.397* T_{ij}, *minibus* = 0.428* T_{ij}, *others* = 0.108* T_{ij}

  where d_{ij} is the distance from zone *i* to zone *j* which would be picked from the distance matrix, and T_{ij} is number of person trips between zone *i* and zone *j* which would be picked from the OD matrices.

Hence at the end of the calculation, five origin-destination matrices for the five modes are produced for the low-income group, for the work purpose trips. To check the accuracy of the result, average distance of each mode and modal share are calculated and checked against the observed average distances of modes. The average mode distances and modal shares are used to calibrate the mode split matrices to get satisfactory result. If the modal shares and distances are not replicated well, an iterative procedure is employed by slightly varying the distance groupings. For example, for low income trips, a d_{ij} between 0 and 2km did not give good result. Thus trials are made by varying group margins with values of 2.1km, 2.2km etc. till the model result converges with the observed values. These adjustments are needed because the mobility matrices are prepared with discrete distance classes, while the impedance function in the gravity model is continuous.

The generalised form of the methodology applied for the modal split model can be represented as follows:

Table 6.3: A general form of mobility matrix

Trip Distance Mode	**G_1**	**G_2**	**... G_k**	**... G_m**
m_1	S_{11}	S_{12}	...S_{1k}	... S_{1m}
m_2	S_{21}	S_{22}	... S_{2k}	... S_{2m}
$\vdots$				
m_f	S_{f1}	S_{f2}	... S_{fk}	... S_{fm}
$\vdots$				
m_n	S_{n1}	S_{n2}	... S_{nk}	... S_{nm}
Total	100%	100%	100%	100%

For $d_{ij} \in G_k$, *then* $M_f = S_{fk} \times T_{ij}$

where d_{ij} is distance between zone i and j, G_k is the distance group, M_f is the number of trips using mode m_f, S_{fk} is share of mode m_f in distance group G_k , and T_{ij} is the number of person trips between zone i and zone j .

Table 6.4 shows results of the model output against observed values after calibration of final matrices.

Table 6.4: Comparison of model output and target

	Low Income				**Medium Income**				**High Income**			
	Percentage		Average Distance		Percentage		Average Distance		Percentage		Average Distance	
	Observed	Model	Observed	Model	Observed	Model	Observed	Model	Observed	Model	Observed	Model
Walk	67.2%	68.5%	1.41	1.31	51.2%	49.5%	1.4	1.65	32.6%	31.9%	1.4	1.63
Car	1.3%	1.3%	7.38	8.00	9.0%	9.3%	7.4	7.01	21.0%	21.1%	7.4	7.27
City Bus	7.7%	7.5%	7.45	8.11	15.5%	16.0%	7.5	7.08	23.8%	24.5%	7.5	7.45
Mini Bus Taxi	21.8%	20.7%	5.41	5.84	19.2%	19.9%	5.4	5.66	13.8%	11.1%	5.4	5.30
Others	2.0%	2.1%	8.12	9.00	5.1%	5.2%	8.1	7.85	8.9%	11.4%	8.1	9.03
	Average		3.00	3.00			4.14	4.14			5.49	5.50

It can be seen that the modal split methodology captures all significant modes of transport in the city. An origin-destination matrix specifically for the walk mode is generated. Likewise an origin-destination matrix for public transport modes is generated. Had there been significant usage of bicycles in the city, cycling would have been included as well.

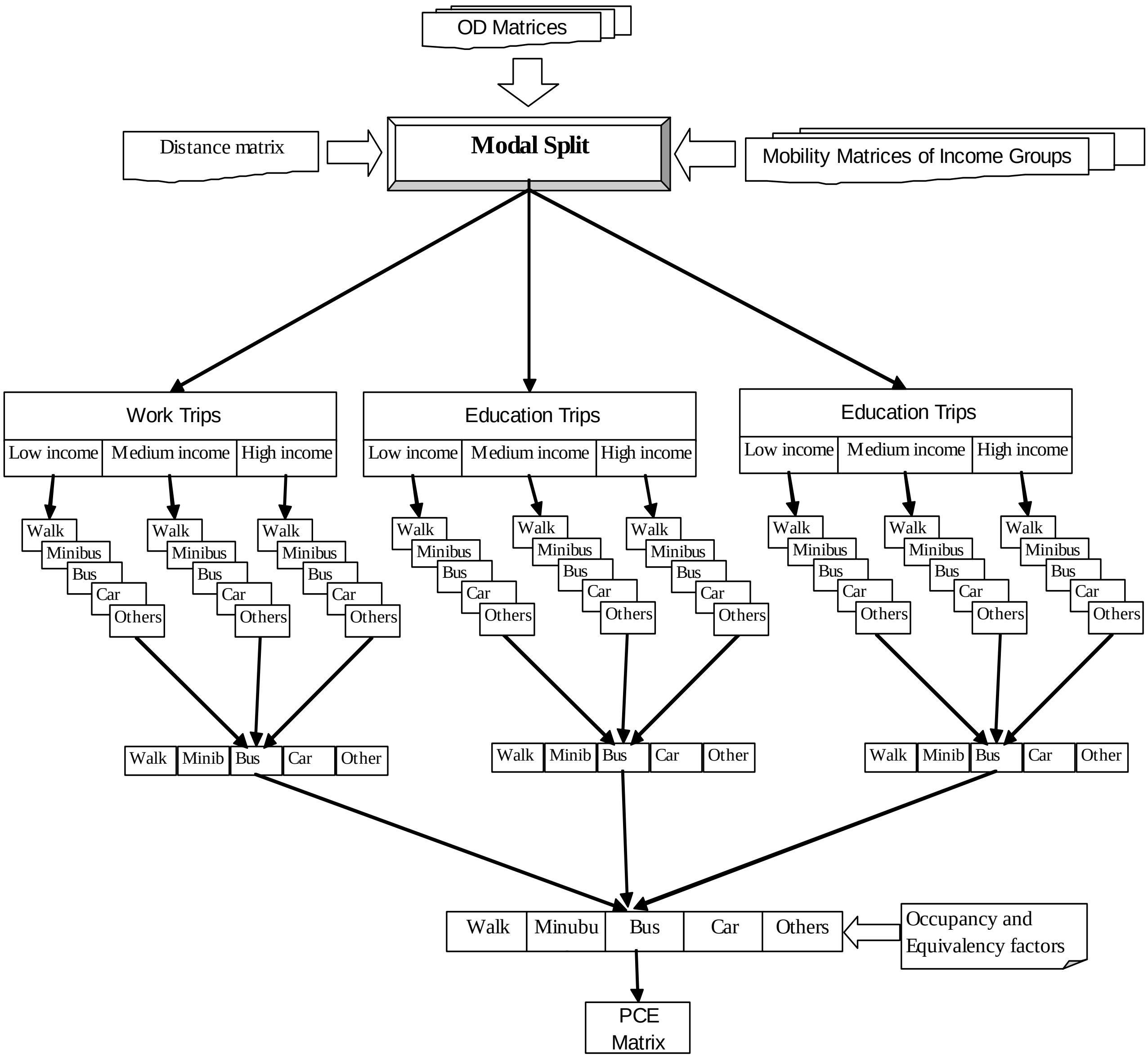


Figure 6.2: Diagrammatic presentation of modal split model

6.4 Traffic assignment modelling

Two assignment methods were employed: all-or-nothing assignment and capacity restraint assignment. A computer program using VBA language was developed to do both assignment models within the spreadsheet set-up of the model.

All-or-nothing assignment

The "all-or-nothing" assignment procedure (AoN) loads the trips between each origin and destination pair on the shortest travel time path in the simplified network connecting this pair. The problem is thus that of finding the minimum travel time paths connecting each OD pair for a given set of link travel times (Sheffi 1985).

Box 4.1: *Floyd's all-pairs shortest path algorithm (Foster 1995)*

procedure sequential floyed
begin
$I_{ij}(o) = 0$ if $i = j$
$I_{ij}(o) = $ length $((v_i, v_j))$ if edge exists and $i \neq j$
$I_{ij}(o) = \infty$ otherwise
for $k = 0$ to N - 1
  for $i = 0$ to N - 1
    for $j = 0$ to N - 1
      $I_{ij}(k+1) = \min(I_{ij}(k), I_{ik}(k) + I_{kj}(k))$
    endfor
  endfor
endfor
$S = I(N)$
end

Two algorithms are popular for the identification of shortest paths in a network: Floyd's, and Dijkstra's. Floyd's algorithm calculates the shortest path from all nodes to *all other* nodes in a given directed or undirected graph. In comparison, the algorithm of Dijkstra only calculates the shortest path from *one* node to all others (Foster 1995). Floyd's algorithm was chosen for this study (Box 4.1).

The output of the all-or-nothing assignment is Average Daily Traffic (ADT) on the road network. The input data for the model are the traffic (PCE) matrix and the attributes of links in the network. The link attributes used for the model are: length, number of lanes and speed.

The ADT's estimated for Addis by the AoN assignment model show a good fit with available traffic volume (ADT) counts. The correlation coefficient between the counted volume and the assigned volume is 0.95. The percent RMSE is 14%. It should be underlined that this fit is satisfactory indeed, since the estimates derived from the four step model are based on data that are completely independent of the traffic count data. The fit with observed traffic flows thus is a real validation of the simplified model's capability to predict traffic volumes on the main arterial road network well.

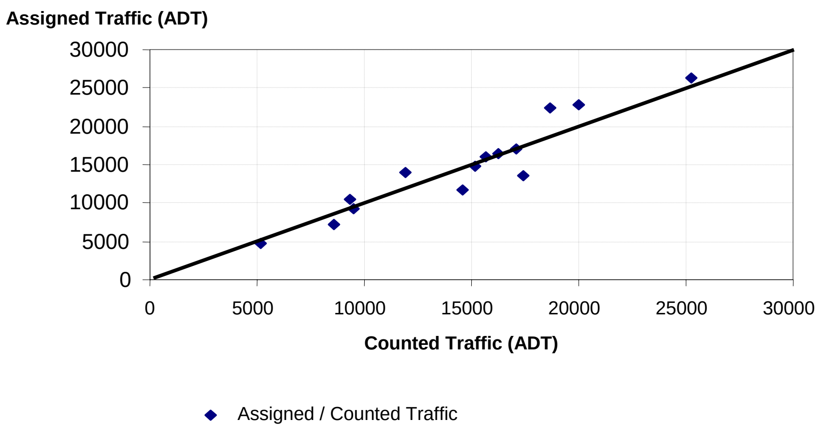
Table 6.1 shows the percent differences in volume; the volumes are two-way average daily traffic. According to Wegmann and Everett (2005) the proposed standard correlation coefficient is greater than 0.88 and a suggested appropriate value of Percent RMSE is less than 30%. And a desirable error range for daily link volumes is 20% to 25% for an ADT range of 10,000 to 25,000. However, while commonly it is advised that the comparison is made for at least around 60% of the network links, in the current study traffic count data were only available for 14 links (23%, quite evenly spread though).

Table 6.1: Comparison of counted traffic and assigned traffic

Link	Counted Traffic without freight (ADT)	Model Output (ADT)	Deviation of model
7-38	19991	22905	15%
9-48	17082	17099	0%
12-38	17445	13524	-22%
27-70	15646	15951	2%
36-37	16209	16531	2%
36-49	9472	9230	-3%
40-41	14581	11758	-19%
41-74	15189	14726	-3%
47-53	9293	10383	12%
51-52	11904	13962	17%
57-60	25250	26317	4%
59-60	18635	22448	20%
64-66	8544	7163	-16%
68-69	5135	4793	-7%
	204376	206790	1.2%

Figure 6.3 shows the comparison between the assigned traffic and the counted traffic. The AoN traffic assignment can also be carried out separately for specific modes of transport. For public transport modes this allows the use of the network consisting of the actual routes only (and the assignment to use the number of buses rather than pce). The AoN assignment for public transport reflects its normal practice of serving fixed routes.

Figure 6.3: Comparison of assigned and counted traffic volumes



Applying the assignment procedure to bicycle traffic on the simplified road network cannot be expected to be very useful, since the actual routes used by cyclists are likely to differ significantly from the ones included in the simplified network. Pedestrian traffic cannot be described at all with the simplified road network. In both cases, the output of the mode split model step (OD matrices for pedestrian and for bicycle traffic – including the estimated intra-zonal volume) can best be used as the starting point for route infrastructure planning for these modes per city district, in combination with the actual detailed road network.

Capacity restraint assignment

An alternative to the AoN traffic assignment procedure that is often used is the so-called capacity restraint assignment. Among the various assignment approaches that take into consideration the effect of congestion, *incremental* assignment is generally considered a realistic approach (Ortúzar and Willumsen 1998). This procedure has also been incorporated in the model presented in this paper. In it, step by step a certain percentage (e.g. 25%) of the total traffic O/D matrix is assigned to the network in batches, and in each step the link travel time is recalculated as a function of the traffic volume on the link already assigned (cumulatively) in preceding steps.

Different relationships can still be assumed for the increase in travel time with increasing traffic density. For example the following BPR (US Bureau of Public Roads) formula presented by both Bruton (1988) and Caliper (2001):

$$t = t_f \left[1 + \alpha \left(\frac{v}{c} \right)^{\beta} \right]$$

where t is congested link travel time, t_f is link free flow travel time, v is link volume, c is link capacity, and α and β are calibration parameters with 0.15 and 4 commonly used values respectively. However, it is questionable whether this relationship is realistic for an urban road network such as Addis. A speed-flow curve derived by ERA (2005) shows a much stronger increase of travel times with increasing congestion (V/C ratio), as is shown in Figure 6.3 below. For a sensible application of the capacity restraint traffic assignment, the best approach appears to be to measure the actual average speed/flow relationship on a number of important routes in the city (longer routes along the same type of road, including several intersections).

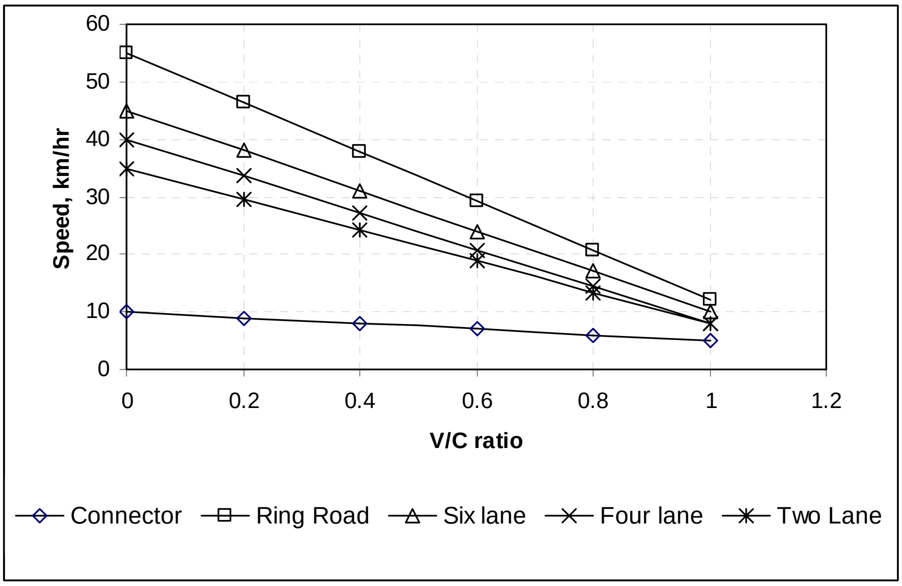


Figure 6.3: Speed flow relationship

For the incremental capacity restraint approach, peak hour traffic per traffic direction of course has to be considered. Unfortunately, reliable peak hour traffic counts for Addis were not available to us to check the accuracy of the capacity restraint assignment. Assuming a constant peak-hour/ADT ratio, the fit between the capacity restraint model estimates and the "observed" peak flows turned out to be considerably worse than that of the AoN. However, this cannot be considered a conclusive test, since according to ERA studies the peak/ADT ratio in Addis appears to vary between 7.5% and 13%. An application to a case where such counts are available is required to pass a judgement on the usefulness of applying this procedure in the simplified model.

One should bear in mind that the simplified travel demand model presented here is not meant for traffic flow analysis or a study of traffic management options. The strength of the model lies in its capability to investigate the likely future traffic flows along the main arterial corridors in a city depending on the type of urban development scenario that materializes (in terms of activity locations/land use, trip rate development and modal choice) , as a tool to support long-term strategic urban transport planning.

7. Conclusions

- In the travel demand model presented in this paper, the simplification has two main dimensions. The first is the use of a limited amount of data, a combination of administrative data (such as population numbers) and data that can be obtained relatively easy with a modest scale and size household travel survey (questionnaires and surveying procedures and instructions are available from the authors in addition to the simplified model code). Zonal data requirement is reduced by using a minimum number of zones. Calibration is carried out by a simple procedure using average trip distance as the key parameter.

- The second dimension is the use of a simple and transparent model structure and calculation procedure, modelled within a spreadsheet structure, with all calculus and algorithms (and source codes) accessible –and adaptable- to the model user. It is expected that competent staff of a municipality in a developing city can utilise the model independently.

- It is demonstrated by the application to Addis Ababa that the simplified model can predict passenger traffic on the main arterial urban road network with satisfactory accuracy. Hence, it can be utilised for strategic transport network planning.

- The simplified model presented in this paper provides an overview of the entire urban passenger transport system, covering all modes of travel: for car and public transport traffic it provides estimates of the traffic flows on the main arterial road network, for pedestrian traffic (and where applicable bicycle traffic) it provides estimates of OD flows between traffic zones. This is particularly important for low-income cities where a high percentage of all trips are pedestrian and two-wheeler traffic.

- The simplified model can be used for strategic planning at corridor level. It will help in identifying future main urban route corridor capacity requirements. The model also allows analysing the consistency of different network improvement alternatives with future activity locations/ land-use patterns. Not only is the model useful for future planning, but is also useful for the present. It can be applied for prioritising current road investment proposals on the main network.

- The simplified model is unable to predict precise future traffic volumes on specific road sections (and intersections) that could serve as an input to detailed road designs. However, in this respect there is no fundamental difference with the more complex standard travel demand model, which is equally unable to provide such accurate detailed forecasts, given the error margins in the input data and the uncertainty about the stability of the model parameters over time.

- The simplifications used increase the transparency of the forecasts and facilitate a clear comparison of long-term urban transport scenarios. The mobility matrices have the added advantage of allowing a direct robust estimate of the total annual operational costs and travel time cost of the transport system for all modes of travel, including walking, likely to result in future from specific development scenarios –combinations of land-use scenarios and transport policy choices.

- The test of the simplified model on Addis Ababa indicates that the final fit between the predicted and the measured traffic flows most of all depended on utilising accurate trip production and attraction values (the estimates of average trip distance per trip purpose and income group and of the mobility matrices being rather robust). Hence, giving detailed attention to the trip generation model is recommended.

- The model test on Addis Ababa showed that the use of straight-line distances between traffic zones gave the best output in the OD step (rather than using shortest distances along the simplified arterial road network). However, by introducing a detour factor on the arterial routes (based on fitting estimated model OD flows to large OD flows of which estimates can be derived from the travel survey), a comparably good OD matrix estimate can be achieved (not shown in this paper). In view of the advantage of reflecting the impact of creating a new arterial route (e.g. a new ring road) at trip distribution stage it is recommended to calibrate the OD model with a factored arterial road distance.

- It is expected that in cities with (unlike Addis Ababa) significant physical barriers, such as rivers, the use of factored simplified road network distances will be required anyway to arrive at correct OD matrix estimates (to be tested in further applications of the simplified model).

- By using aggregate mobility matrices per travel market segment the simplified model sacrifices the analysis of underlying determinants of modal choice such as travel time and cost differences, fear for traffic accidents or violence affecting the use of certain modes, comfort and status considerations, etc. However, for strategic long-term planning the sacrifice is considered to be small, in view of the likelihood that the elasticity's (parameters) concerned will change over time in a non-predictable manner, and the fact that reliable forecasts of some of the determining factors (the attitudinal ones in particular) cannot be made.

- This argument doesn't imply that the analysis of modal choice determinants is unimportant. On the contrary: it provides very useful indications of the effectiveness that different policies to influence modal choice are likely to have. Yet, such analysis can more successfully and efficiently be carried out in its own right, without being incorporated in the travel demand model meant for long-term strategic planning.

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Corrections to WTPP Number 14.1 May 2008

Article: Sustainable happiness and the journey to school
Author: Catherine O'Brien

Pg 19: Indentation to indicate quote:

… Sunday. He writes about this in the context of sustainable happiness.

> *Ciclovia* attracted over 1.5 million people every week to walk, run, bike or skate. Despite the multiple issues happening in the country, this was the safest and most enjoyable place. On average, people were doing 50 minutes of physical activity but stayed on the *Ciclovia* for over 4 hours, enjoying other people's company. Obviously this is very respectful of people, the environment and future generations (G. Peñalosa, 2007).

Pg 16: "As adults, those journeys…" – "ours" should be "our"

Pg 20: Indentation to indicate quote:

… happiness and reinforce the 'virtuous circle' described by Martin (2005).

> Happiness and sociability go hand in hand…research has also shown that we have a higher quantity and quality of social interactions when we are happy…Happy people find social encounters more satisfying, they adopt a less cautious social style, and they are more inclined to be cooperative and generous. What is more, this link between sociability and happiness works both ways; sociable people, become happier and happy people become more sociable, creating a virtuous circle (p 30).